

**CLAIMS**

1. A process for the production of alcohols comprising the hydroformylation of an olefin or olefin mixture followed by catalytic hydrogenation, wherein the hydrogenation is performed in a series of at least two reactors and water is added  
5 to the material discharged from the first reactor that is to be hydrogenated in the second reactor, in an amount such that in the second reactor, all the water present is dissolved in the organic phase.
2. A process for the production of alcohols comprising the hydroformylation of  
10 an olefin or olefin mixture followed by catalytic hydrogenation, in which process the hydrogenation is performed in a series of at least two reactors, water is added to the hydroformylation reactor, no further water is added in the first hydrogenation reactor and water is added to the second hydrogenation reactor.
- 15 3. The process according to claim 1 or 2 in which water is carried over from the hydroformylation reactor or a demetalling or washing step downstream of the hydroformylation reactor, into the first hydrogenation reactor, the amount of water carried over being such that all the water present in the first hydrogenation reactor is dissolved in the organic phase to be hydrogenated in the first hydrogenation  
20 reactor.
4. The process according to claim 3 in which further water is added to the material entering the second hydrogenation reactor, the amount of water added being such that all the water present in the second reactor is dissolved in the  
25 organic phase to be hydrogenated therein.
5. The process according to any of the preceding claims in which the sulphur content of the feed to the first hydrogenation reactor is below 10 wt. ppm, preferably below 5 ppm.

6. The process according to any of the preceding claims in which the olefin or olefin mixture used for hydroformylation has a sulphur content below 10 wt. ppm, preferably below 5 ppm, more preferably below 1 ppm.
- 5 7. The process according to any of the preceding claims in which the chlorine content of the feed to the first hydrogenation reactor is below 10 wt. ppm, preferably below 5 ppm.
8. The process according to any of the preceding claims for the production of C<sub>6</sub> to C<sub>15</sub> alcohols from C<sub>5</sub> to C<sub>14</sub> olefins or olefin mixtures.
- 10 9. The process according to any of the preceding claims in which the hydroformylation is performed at elevated temperatures and pressures using a cobalt catalyst.
- 15 10. The process according to claim 9 in which cobalt species are removed from the product of hydroformylation prior to hydrogenation in the first hydrogenation reactor.
- 20 11. The process according to claim 9 or 10 in which the product of hydroformylation is treated to remove cobalt species so that the cobalt content is below 2 wt. ppm prior to hydrogenation.
12. The process according to any of the preceding claims in which the hydroformylation is performed at pressures from 50 to 350 barg, preferably 150 to 350 barg, most preferably from 275 to 325 barg and temperatures from 165 to 185°C preferably from 170 to 180°C.
- 25 13. The process according to any of the preceding claims in which the hydroformylation reaction is performed in a series of at least two reactors.
- 30

14. The process according to any of the preceding claims in which the gas composition in the hydroformylation reactor(s) is controlled by recycle of unreacted gasses from hydroformylation.

5 15. The process according to claim 13 or 14 wherein the hydrogen level in the second (and any subsequent) hydroformylation reactor(s) is replenished by balancing the composition of recycle gasses and/or by introducing unreacted gasses from the downstream hydrogenation reactor used to convert aldehydes in the final product of hydroformylation into alcohols.

10

16. The process according to claim 13, 14 or 15 in which a series of at least three hydroformylation reactors is used, and a hydrogen rich gas, comprising recycle gas from the hydroformylation reaction and/or from the downstream hydrogenation section, is fed to the third reactor.

15

17. The process according to any of the preceding claims in which the hydroformylation catalyst is cobalt and cobalt catalyst species are removed by injection of base such as caustic soda and/or sodium carbonate into the reaction product in a decobalter vessel following the final hydroformylation reactor.

20

18. A process for the production of alcohols comprising the hydroformylation of an olefin or olefin mixture, aldolisation of at least a portion of the aldehyde or aldehyde mixture produced in hydroformylation, and catalytic hydrogenation of at least a portion of the aldolisation product, wherein the hydrogenation is performed in a series of at least two reactors and water is added to the material discharged from the first hydrogenation reactor that is to be hydrogenated in the second hydrogenation reactor, in an amount such that in the second reactor, all the water present is dissolved in the organic phase.

25

30 19. The process according to claim 18 in which water is carried over from the aldolisation reactor into the first hydrogenation reactor, the amount of water carried over being such that all the water present in the first hydrogenation reactor

is dissolved in the organic phase to be hydrogenated in the first hydrogenation reactor.

20. The process according to claim 19 in which further water is added to the  
5 material entering the second hydrogenation reactor, the amount of water added being such that all the water present in the second reactor is dissolved in the organic phase to be hydrogenated therein.

21. The process according to any of claims 18 to 20 wherein the olefin or olefin  
10 mixtures comprises C<sub>2</sub> to C<sub>4</sub> olefins.

22. The process according to claim 21 using rhodium hydroformylation catalyst.

23. The process according to claim 21 or 22 using a phosphorus ligand in its  
15 hydroformylation reactor.

24. The process according to claim 23 wherein the phosphorus ligand is triphenylphosphine.

20 25. The process according to claim 23 wherein the phosphorus ligand is an organic phosphite.

26. The process according to claim 25 wherein the organic phosphite is 6,6'-  
[[3,3',5,5'-tetrakis(1,1-dimethylethyl)-1,1'-biphenyl]-2,2'-diyl] bis(oxy)] bis-  
25 dibenzo [d,f] [1,3,2]-dioxaphosphin.

27. The process according to any of claims 21 to 26 wherein a C<sub>8</sub> alcohol is produced from propylene.

30 28. The process according to any of claim 21 to 26 wherein a C<sub>9</sub> alcohol is produced from ethylene.

29. The process according to any of claims 21 to 26 wherein a C<sub>10</sub> alcohol or alcohol mixture is produced from butene or from a butene mixture.

30. The process according to any of the preceding claims in which the  
5 hydrogenation catalyst is a cuprous chrome catalyst.

31. The process according to claim 30 in which the hydrogenation catalyst contains from 20% to 40% by weight of each of copper and chromium based on the total weight of hydrogenation catalyst including any support, preferably from  
10 25% to 35% of each of copper and chromium, more preferably from 28% to 32% of each of copper and chromium, most preferably 29% to 31% of each of copper and chromium.

32. The process according to any of claims 1 to 29 in which the hydrogenation  
15 catalyst comprises a monometallic or bimetallic or trimetallic catalyst composition on a solid support.

33. The process according to claim 32 wherein the support is selected from alumina or silica-alumina or a carbonaceous support.  
20

34. The process according to claim 33 wherein the catalyst composition further comprises an acidity modifier.

35. The process according to claim 34 wherein the acidity modifier comprises a  
25 member of Group IA or IIA of the Periodic Table of the Elements.

36. The process according to claim 35 wherein the acidity modifier comprises magnesium, sodium or potassium, or a compound containing magnesium, sodium or potassium.  
30

37. The process according to any of claims 1 to 29 in which the catalytic hydrogenation uses a transition metal hydrogenation catalyst dissolved in an ionic liquid.

- 5 38. The process according to claim 37 wherein the transition metal is selected from nickel, cobalt, copper, palladium, chromium, ruthenium and rhodium, or a mixture of any two or more thereof.

39. The process according to claim 37 or 38 wherein the ionic liquid comprises in  
10 combination a first component selected from  $[\text{BF}_4]^-$ , halide anions,  $[\text{PF}_6]^-$ ,  $[\text{CF}_3\text{COO}]^-$ , and  $[\text{SbF}_6]^-$ , and a second component selected from  $[\text{emim}]^+$ ,  $[\text{bmim}]^+$ , any other disubstituted imidazolium, the substituents being C1-C4 alkyl, or  $[\text{NBuPy}]^+$  or another suitable alkylammonium cation.

15 40. The process according to any of the preceding claims in which the product from the first hydrogenation reactor passes in a line to the second hydrogenation reactor and water is injected into the line and the mixture passes to a mixer whereby the water and the product are mixed so that the water is dissolved and/or entrained in the product, and the mixture is then passed to the second  
20 hydrogenation reactor where it passes through a catalyst bed at a temperature of 170 to 190°C at a hydrogen pressure of 40 to 200 barg.

41. The process according to claim 40 in which from 1 to 2 wt % of water based on the weight of organic material is injected.

25

42. A mixture of  $\text{C}_5$  to  $\text{C}_{13}$  olefins comprising at most 90 mol % of normal olefins, which mixture is useful in the production of alcohols by hydroformylation of the olefin mixture followed by hydrogenation, said olefin mixture containing no more than 10 wt. ppm, preferably no more than 5 ppm and more preferably no more  
30 than 1 ppm, most preferably below 0.1 ppm, sulphur and no more than 10 wt. ppm preferably no more than 5 ppm and more preferably no more than 1 ppm, most preferably below 0.1 ppm chlorine.

43. The olefin mixture according to claim 42 wherein more than 50 wt. % of the mixture comprises C<sub>8</sub> olefins.

5 44. A hydrogenation feed stream comprising aldehydes containing from 6 to 15 carbon atoms useful in the production of alcohols by hydrogenation, said hydrogenation feed stream containing no more than 10 wt. ppm, preferably no more than 5 ppm and more preferably no more than 1 ppm, most preferably below 0.1 ppm, sulphur and no more than 10 wt. ppm, preferably no more than 5 ppm,  
10 and more preferably no more than 1 ppm, most preferably below 0.1 ppm chlorine.

45. The hydrogenation feed stream according to claim 44 comprising aldehydes containing nine carbon atoms, useful in the production of C<sub>9</sub> alcohols.